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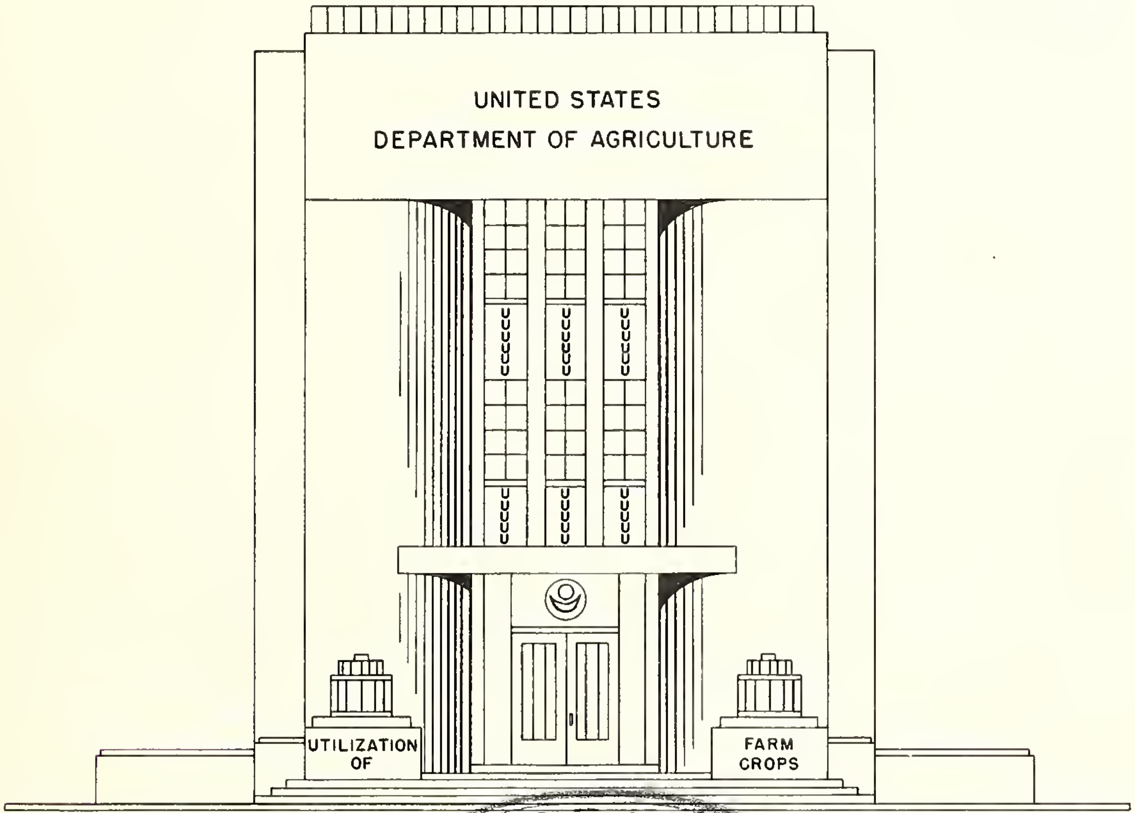
UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service

THE CONTRIBUTION THAT SUGARCANE BAGASSE CAN MAKE TO THE PAPER AND BOARD INDUSTRIES



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By

Elbert C. Lathrop and Samuel I. Aronovsky

NOVEMBER 1954

EXCEPT FOR COVER,
PAPER USED IN THIS BULLETIN CONTAINS
49 PERCENT BLEACHED WHEAT-STRAW PULP
MADE BY THE MECHANO-CHEMICAL PROCESS
DEVELOPED AT THE NORTHERN UTILIZATION
RESEARCH BRANCH, PEORIA ILLINOIS.

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THE CONTRIBUTION THAT SUGARCANE BAGASSE CAN MAKE TO THE PAPER AND BOARD INDUSTRIES[1]

By

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INTRODUCTION

Sugarcane bagasse as a raw material has attracted the paper industry for a long time because of its annual availability in large quantities as a byproduct. Hundreds of technical reports and patents relating to conversion of bagasse into pulp, papers, and boards are available for review. No industrial success and, indeed, numerous industrial failures resulted from this work until 33 years ago, at which time the manufacture of insulating building materials from bagasse was started and proved successful. However, successful manufacture of paper from bagasse did not take place for about another 18 years. Now, at least 10 plants are producing paper or board products from bagasse which are industrially acceptable in the respective countries in which they are being manufactured (1). With perhaps no exceptions, papers so made would not meet industrial standards in the United States.

Economic and technological factors have been responsible both for failures of the past and for differences in quality of the products now being made. At present there are very great differences in economic conditions between countries and between competitive situations within countries. As competition becomes more intense, quality of product plays an increasingly important role in industrial survival until, under the most severe conditions, that product which has superior inherent properties outperforms and takes first rank.

Much has appeared of late in the daily and technical press about new processes for pulping bagasse, new mills to be built, and, particularly, about making newsprint from bagasse alone. These stories have been written for many purposes, political, promotional, and technical. Most of the reports have, of course, some basis in fact, but the bias with which some were written and the unqualified character of many of the statements have proved very confusing. On the one hand, a person might be led to believe that bagasse is ideally suited to make almost any kind of paper and on the other that its utility is quite limited. Neither opinion would be correct.

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[1] Presented at the Latin American Meeting of Experts on the Pulp and Paper Industry, Buenos Aires, Argentina, October 26, 1954, sponsored by the United Nations' Economic Commission for Latin America, Technical Assistance Administration, Food and Agriculture Organization.

[2] One of the Branches of the Agricultural Research Service, U. S. Department of Agriculture.

It is the purpose of this publication to present factual information concerning the kinds of pulps and papers, from the poorest to the best, that our present knowledge tells us may be made from bagasse. Various pulping methods that may be used, based on industrial experience, will be described briefly. Chemical requirements, yields, and general qualities of pulps produced by the several methods will be discussed. It is hoped that information of this type will be useful in arriving at decisions that will lead to commercial successes in using bagasse in the paper and board industries.

In recent years renewed interest in use of annual plants for papermaking has resulted in extensive research by pulp and paper laboratories of a number of governments. Published researches of these institutions have cleared away many earlier misconceptions and form the basis of a rational technology. Our knowledge of pulping methods and of pulps and papers that may be made from annual plants now compares rather faborably with our knowledge of wood and is indeed advanced over that of tropical woods. It has been shown that rational methods for pulping specific annual plants must be based on a knowledge of their physical and chemical characteristics so that pulping chemicals and conditions may be properly designed. In general, pulps made from annual plants do not have the same properties as those made from pulpwoods and cannot be expected to behave exactly alike on the paper machine or to make identical papers. In some cases these pulps will make papers or boards superior to those made from wood pulps; in other cases their best use is in blends with wood pulps. Often in the latter use, papers superior to those made wholly from wood pulps may be produced.

Physical and Chemical Characteristics of Bagasse:

Characteristics of the fibrous elements of the cane stalk as it enters the sugar mill are described as follows: The outside of the stalk (rind) comprises a relatively tough ring. The inside consists of soft, medullary tissue in the cells where the sugar is deposited. Lengthwise through this tissue run numerous fibrovascular bundles of various sizes so placed that the smallest are packed near the outside and the larger ones, less abundant, are distributed towards the center. The rind is formed of thick-walled, elongated cells of hard or sclerenchymatous fibers. The fibrovascular bundles comprise groups of fibers and ducts. The pith, or parenchymatous cells, are short, broad, and of low resistance to penetration. These cells group around and adhere both to the fibrovascular bundles and the rind fibers. The oustide of the rind often appears glassy, carries a coating of wax, and may be of a number of colors. At intervals in the length of the stalk, which vary in accordance with conditions of growth of the cane, the fibrovascular bundles send branches outwards, thereby forming a portion of dense tissue called the node. Neither the pith nor perhaps the tissue concentrated in the node is suitable for papermaking (2). Fibers from cane leaves are also of little or no value in paper or board manufacture since they are so short that most are destroyed or lost during pulping and washing operations. Generally leaves and trash are removed from the cane in the field, but when mechanical harvesting of cane is practiced the bagasse will contain more or less trash and leaves.

It will be noted that cane is composed of three rather different elements, pith, fibrovascular bundles, and bundles of rind fibers. Browne (3) made a careful analysis of the percentage of these elements in several varieties of cane, results of which are given in Table I. The proportion of these elements will vary depending on a number of factors, chiefly the variety of cane. Variation in pith and fiber content of three varieties of cane grown in Florida is given in Table 2. Bagasse also contains a variable amount of soil and dirt, depending on soil character and method of harvesting. If the leaves are burned in the field, the cane will carry many carbon particles. The proximate physical composition of five different samples of commercial bagasse from widely separate locations is given in Table 3.

Moisture content of bagasse from the cane mill may vary from 41 to 51 percent, and often runs about 48 percent. Sucrose remaining in the bagasse varies from 2 to 5 percent depending on conditions. Keller (4) states that the color of bagasse will vary from greyish-white to very dark green. The material is nonhomogeneous in size, varying from dust that will pass a 60-mesh screen to particles around 6 inches long by 3/8 inch in diameter. Usually about 97 percent will pass a 1-inch square opening. The analysis on an "as produced" basis is about as follows:

	Percent
Moisture	49
Fiber and dirt	45
Soluble solids	6

The proximate chemical composition of samples of bagasse representative of different varieties and from different countries is given in Table 4. The sample of Louisiana bagasse is representative of commercially stored bagasse. The remainder of the samples were dried immediately at the sugar mill.

For comparison the proximate chemical composition of certain pulpwoods is given in Table 5. The fiber dimensions of sugarcane, some cereal straws, and certain pulpwoods is given in Table 6.

Papermaking Possibilities of Bagasse as Indicated by Physical and Chemical Properties:

Knowledge of the relationships between physical and chemical composition of fibrous raw materials, or of their ultimate fibers and their utility in papermaking has become extensive. An analysis of the data presented above leads to the following conclusions:

The composition of bagasse is variable, depending on variety, soil, method of harvesting, milling, and other factors. All bagasse contains dirt and if the leaves are burned in the field, it is likely to contain carbon particles. In any case, dirt and carbon are undesirable in papermaking. While a certain amount of these impurities can be tolerated in board manufacture, their presence in pulps used for high-grade papers, or those intended for bleaching, will result in extra expense for chemicals, lower yields, and pulps of poorer physical properties.

Bagasse is composed of three elements, to which must be added short leaf fibers if much leaf enters the mill with the cane. Two of these elements are fibrous, namely, fibrovascular bundles and rind fibers. The third element is parenchymatous tissue, or pith, a material not fibrous but composed of soft, rather unorganized tissue. The surface area of pith is vastly greater than that of an equal weight of fibrous elements. The ratio of the three elements to each other will depend on several factors, chiefly variety of cane.

Chemical composition of different samples of bagasse varies somewhat, but this variation is less than that found in physical composition such as rind, fibrovascular bundles, and pith. Canes that are more mature when harvested will have higher lignin content. Evidence accumulated in studying the chemical composition of annual plants shows that the relationship between lignin, cellulose, and pentosan contents of straws, stalks, and cobs may be altered by plant breeding. A comparison of chemical composition of respective samples of pith and fiber obtained from whole bagasse samples shows that the pith contains more ash, pentosans, and 1 percent NaOH solubles, and less cellulose than the fiber. The greater ash content is due to the greater surface area of the pith which absorbs more dirt.

The percentage of hot-water-soluble material is greater in the whole bagasse samples than in either the fiber or pith separated from them. This is due to the fact that separation of pith and fiber was carried out by a wet process. It will be noted that the hot-water-soluble material is lower in the stored bagasse than in the other samples. During the storage period sugars present in the fresh bagasse are destroyed by fermentation processes.

Compared with the chemical composition of the pulpwoods, shown in Table 5, fiber separated from bagasse is lower in lignin content in most cases than either softwoods or hardwoods and contains more pentosans and more material soluble in 1 percent NaOH. Bagasse fiber compares rather favorably with pulpwoods in cellulose content. In chemical compsoition, bagasse more closely approximates hardwoods than softwoods and, therefore, its papermaking properties more closely resemble those of hardwoods.

Comparisons with Wood Pulps:

Bagasse is easier to pulp than hardwoods and requires less chemicals for pulping. This is due to the greater ease of penetration of chemicals into the fibrous elements of bagasse as compared with the dense chips of pulpwood, and also to the lower lignin content of bagasse.

Normally, pulps made from hardwoods or from stalks and straws contain more pentosans than softwood pulps. In general, pulps which contain higher concentrations of pentosans, up to a certain maximum, have been found to beat faster and to develop greater strength than corresponding pulps containing less pentosans. On the other hand, pulps containing high percentages of pentosans tend to make denser and harder surfaced papers with lower opacity than those produced from softwood pulps. In the manufacture of glassine papers and corrugating medium, high-pentosan-containing pulps are a necessity. Use of high-pentosan pulps as blends with other pulps, particularly groundwood or weaker pulps, produces improved paper products. Using prehydrolysis treatments it is possible to prepare pulps from bagasse, straws, and hardwoods that are lower in pentosan content and which, therefore, produce less dense, more opaque, and softer papers. These treatments, however, lower pulp yields and increase costs.

A direct relationship exists between the dimensions of fibers and their papermaking properties. Tear resistance is associated with fiber length. Short-fibered pulps are deficient in this property. Since strength in papers is attributed to bonding of individual fibers. it follows that fibers with a high ratio of length to diameter will, other things being equal, contribute greater strength than broader fibers of the same length. "Formation" in papers is associated with fiber length and with degree of fibrillation of pulps used. Softwood pulps, having long fibers and often fibrillated by the considerable refining required, produce less well-formed papers than shorter fibered pulps from bagasse or hardwoods. In turn, blending of bagasse or hardwood pulps with longer fibered pulps will produce papers of improved formation and better suited for printing.

Reference to Table 6 shows that bagasse and cereal straws are composed of a number of fibrous elements which differ considerably in dimensions. Rind fibers of the cane are longer than those of the vessel segments (fibro-vascular bundles) and have narrower fiber diameters. They will therefore produce stronger papers, particularly in respect to tear resistance. While rind fibers are shorter than those of softwoods, they are longer than those of hardwoods and will produce more tear-resistant papers than the latter. Cane fibers have a length-to-diameter ratio practically the same as that for softwoods and considerably more favorable than that for hardwoods.

Pith a Major Problem:

Reference has been made to the unorganized character of parenchymatous or pithy material. It will be observed from Table 6 that pith particles of cane or of straws are very short and broad. Taking these facts into account it is easy to see that these particles can contribute little to papermaking unless they can be separated and especially treated to carry out special functions, such as fillers. There can be no mystery as to what happens to pith particles during pulping and papermaking operations. Pulping operations are carried out in order to remove unwanted lignin and other impurities to the extent required for making particular papers or boards. Chemical reactions taking place in pulping are in all cases between the chemicals and the surfaces of materials being pulped. Reactions therefore proceed faster on those particles having greater surfaces. In the case of bagasse, this means that chemicals act much more rapidly on pith than on rind or fibrovascular bundles, due first to the much larger surface of pith and secondly to greater ease of penetration of the chemical into it. In turn, chemicals act more rapidly on fibrovascular bundles than on rind fibers, due to their greater surface area and to the fact that they contain ducts which make penetration of chemicals into them more rapid. These fact have been thoroughly demonstrated in present commercial practice.

Pith therefore uses up chemical more rapidly than fibrous elements and is softened more quickly. Pulps are handled entirely in water suspensions. They must be pumped, dewatered over wire surfaces, and defibered or refined by attrition. All of these treatments contribute to loss of unorganized pithy material from pulps. On the other hand, because of their greater surface areas, pith particles absorb more dirt, which only can be removed by destruction of the pith cells. They, therefore, make bleaching of pulps much more difficult, requiring larger amounts of bleaching agent and resulting in weaker pulps and lower yields. Finally, the drainage rate of pulps has a direct bearing on character and rate of paper-machine operation. Pulps containing pith will drain much more slowly than pulps made from bagasse fibers from which pith has been separated. Since prehydrolysis processes are also chemical, pith will react in these processes more rapidly and to a greater extent than fiber.

PROCESSES FOR PULPING BAGASSE

The most authoritative discussion of this subject will be found in FAO Forestry and Forest Products Study No. 6 (5). That report is the result of a thorough discussion of the subject and unanimous approval of recommendations by pulp and paper specialists called together in Rome, December 3-14, 1952, by FAO. The report on bagasse drawn up by the group assigned to consider nonwoody fibers, of which the senior author was chairman, discusses in detail the processes recommended for commercial use, giving chemical requirements and other pulping directions, yields, and steam, power, water, labor, and bleach demands. The utility of the pulps made from bagasse by different processes is discussed and recommendations are made for use of these pulps alone or in blends with long-fibered pulps to produce papers commercially acceptable in world markets. That report should be studied with care by any group or company contemplating building new facilities for making paper or board from bagasse. In addition, attention is directed to three recent papers by Grant (6) who discusses processes for pulping bagasse and other nonwoody plants.

The Peoria laboratory for a number of years has directed intensive studies to utilization of bagasse fiber and pith. Fortunately, pilot-plant facilities are available to study all commercial methods used for pulping bagasse, with the exception of the Celdecor process. Bleached bagasse pulp made commercially by this process has been tested and its properties in comparison with other types of pulp will be reported. Acid processes are not satisfactory for preparing good pulps from bagasse. Nitric acid is an exception, but since this discussion is limited to commercial processes or those that have undergone large-scale trial, no further reference will be made to the nitric acid process.

Commercial pulps are prepared from bagasse by use of the following chemicals: 1. In pressure vessels--(a) lime alone or in combination with soda ash, caustic soda, sodium sulfite, (b) caustic soda, (c) kraft process chemicals--caustic soda and sodium sulfide or caustic soda and sulfur, (d) sodium sulfite with either soda ash or caustic soda as buffer; 2. Celdecor process--caustic soda and chlorine; 3. mechano-chemical process--(a) lime or lime combinations with soda ash or caustic soda, (b) caustic soda, (c) kraft chemicals.

Development work of the Peoria laboratory has been directed mainly to discovering better ways to produce pulps from nonwoody plants that will meet the rigid requirements of the United States markets, but investigations have been basic and cover a wider field (7). When pulps are produced by the use of lime or combinations of other chemicals with lime, they cannot be bleached and are suitable only for the manufacture of boards or coarse papers. By proper selection of conditions, it is possible to use any of the other pulping methods, to produce either board or coarse pulps, unbleached pulps suitable for use in wrappings and board products, or bleached pulps for use in making a wide variety of printing and other specialty papers.

Selection of a suitable process for commercial use will depend on a number of factors such as kind and quality of papers needed, volume of these products that can be sold, amount of capital available, location of the mill, kind of labor and utilities available, and other local factors. In general, the new mills will be small as compared with new mills in the United States or Europe. In deciding on the pulping process to use, in addition to cost factors such as capital investment and operation expense, it will be well to consider simplicity of operations and equipment and flexibility of setup, and to plan for addition of future capacity or manufacture of higher quality merchandise as the market grows.

Pretreating Methods to Remove Pith or to Clean Fiber:

Dirt and pith should be removed as much as possible before pulping. A variety of ways for doing this is available. By passing moist bagasse from the sugar mill over shaking or vibrating screens, some of the impurities are separated. This is common practice in sugar mills to obtain pith for use in filtering muds. By use of screens with somewhat larger holes, a larger proportion of impurities can be removed.

If bagasse has been baled and stored, a bale breaker must be used. By passing loosened dry bagasse over vibrating screens about one-third of the pith and dirt can be removed, a practice common in pulp mills processing bagasse. Where a large excess of bagasse over fuel requirements exists, and provided the bagasse has been passed through a shredder or similar mill to loosen pith from fiber bundles, a system of screens with larger holes will yield about one-third of the processed material as fairly clean fiber.

The Peoria laboratory has developed three different procedures for obtaining clean fiber and high-grade pith (8). Two of these methods are applicable for use in the sugar mill, the other at the pulp mill (9). Lower price machinery and somewhat simpler procedures based on principles developed are now in operation in the new bagasse pulping mill in Mexico.

The above methods are all purely mechanical. Combinations of chemical and mechanical methods are also in use. Indeed, when whole or partially screened bagasse is pulped in the presence of chemicals, a proportionately larger amount of pith than fiber is destroyed and lost by chemical action and through washing, bleaching, and other treatments.

Another method recommended by some is prehydrolysis of bagasse before real pulping operations. This treatment destroys a certain percentage of pith by chemical action, but more important, since the prehydrolyzed mass must be washed and is very free-draining, a large amount of pith is washed out mechanically. If the processes of prehydrolysis is properly conducted, a considerable percentage of the pentosans in the bagasse can be converted to sugars without too greatly degrading the cellulose. Since pulps produced from this prehydrolyzed material have pentosan contents quite similar to those of softwood pulps, they produce soft papers similar to, but much weaker than, papers from woods pulps.

At Peoria, a basic study of prehydrolysis of bagasse has been made, directed largely to methods for producing rayon pulps. Results indicate that if in the prehydrolysis treatment, using either acid, steam, or water under appropriate conditions, the pentosan content of the material is reduced to too low a value, the cellulose will be seriously degraded. Obviously, these treatments, since they destroy fiber and pith, lead to weak pulps in low yields. Multistage processes always increase costs. These facts should be borne in mind in any analysis of claims made for pulping processes.

Responses to Pulping Conditions Are Variable:

For the purpose of rating pulping characteristics of bagasse from different cane varieties and from different localities, a simple pulping procedure using elevated pressure was worked out. Conditions used and results obtained on a number of samples of separated bagasse fiber are given in Table 7. Pulping conditions were chosen so as to prepare a bleachable pulp but they are obviously not those best adapted to produce a pulp of optimum qualities from any one bagasse. Results of this study illustrate the rather wide differences to be expected in yields and in strengths of pulps obtained from different lots of bagasse. This emphasizes that bagasse is a variable raw material, and any process chosen for industrial use should be capable of simple modification so as to compensate for these variations and avoid production of pulps of uncertain quality.

Pulping by Conventional Pressure Processes:

A comparative study was made by pulping lots of bagasse under standard conditions using the same percentate (12 percent) of soda or kraft chemicals, based on oven-dry material. In this study both whole bagasse and separated fiber from these lots were pulped. Results are given in Table 8. Here, also, a variation in yields and in physical properties of pulps derived from different lots of bagasse is to be noted. There seems to be little choice between pulping with caustic soda or kraft chemicals insofar as yields or quality of pulps are concerned. Use of kraft chemicals produces a somewhat easier bleaching pulp, but this advantage may be offset by other factors, such as odor or cost of sulfur. Striking differences shown in this table are between yields and qualities of pulps obtained from whole bagasse and from separated fiber, respectively.

In considering these results, it must be recognized that all samples of whole bagasse, with the exception of the stored Louisiana sample (cook No. 1001), were dry-screened before baling. They contain therefore only about two-thirds of the pith originally present and are representative of commercially cleaned bagasse used for pulping in most countries except Mexico and Peru.

The sodium sulfite method using soda ash as a buffer, as developed for use with straw by the Northern Utilization Research Branch, is as satisfactory for bagasse pulping as the soda or kraft methods. As in the case of pulping cereal straws by this method, yields of pulp are slightly higher than by use of caustic soda or kraft chemicals, and bleach requirements are generally lower, as shown by the results in Table 9. Unbleached sodium sulfite pulps are very much lighter in color than soda or kraft pulps, a distinct advantage, since they need not be bleached when used to make papers with a brightness of about 50. If caustic soda is substituted for soda ash as buffer, pulp yields will be lower, their color darker, and the pulps will take on more and more properties of caustic soda pulps. The same general differences in yield and quality of pulps from whole bagasse vs. bagasse fiber are obtained as with other processes. The sodium sulfite method has the disadvantage that no suitable process has yet been developed for recovery of chemicals.

Celdecor Process:

This is a well-known commercial continuous process for pulping using caustic soda to produce a semipulp suitable for use in corrugating medium- and low-quality boards, and then completing the pulping to make fine pulps by use of wet gaseous chlorine. The process is being used in a number of countries, particularly on straw, and is used to pulp bagasse in a small mill in the Philippines and in a new mill in Pakistan (10). A mill in

Sao Paulo, Brazil, has just been completed for pulping bagasse by this process. The bagasse is prepared for pulping by a dusting process which removes about one-third of the pith and dirt. Use of chlorine as a pulping, as well as a bleaching agent tends to make a somewhat softer pulp than by other alkaline methods, excepting when prehydrolysis is used. We have not been able to study this method on a laboratory scale. The analysis of a sample of commercially bleached pulp from the Pakistan mill is given in Table 15. In the same table will be found an analysis of a bagasse pulp made by the mechano-chemical process, using an 8-foot Hydrapulper, and bleached commercially. It will be noted that the Celdecor pulp is much lower in strength, particularly in folding endurance, burst, and tensile strengths, and is also softer as indicated by its greater bulk.

Mechano-Chemical Process:

This process (11) was discovered at the Peoria laboratory during the development of better methods for pulping cereal straws. It has been applied to pulping bagasse, although because of the denser character of bagasse fibers more chemicals and a slightly longer pulping cycle are required than for most cereal straws. The process is exceedingly simple. It uses low amounts of chemicals at atmospheric pressures for pulping periods of 30 minutes to about an hour. Steam requirements have proved to be very low since a certain amount of hot black liquor is reused for pulping. Although power requirements were slightly higher than in conventional processes, a new Mexican development in the processing has lowered power requirements considerably. The process is carried out in a modification of the mechanical pulpers found now in most mills, and widely used in repulping waste papers or virgin pulp. For example, when the Hydrapulper is used to carry out the process, a larger rotor is required than is standard for pulping waste, with consequent higher power requirements. By use of the Mexican development mentioned, however, the power is less than is normally required for pulping waste papers. Since the pulpers can be made in sizes from 3 to 20 feet in diameter, and since the pulper may be used also for waste papers or virgin pulps, the process is suited for both very small and very large mills.

Pulping takes place through the reaction of pulping chemicals on fiber or fiber-bundle surfaces. The greater the surface area presented the more rapid is the pulping action. The violent mechanical action continuously producing fresh surfaces in the presence of chemicals during pulping accounts for the very rapid rate of pulping and also for the use of the mild pulping conditions in the mechano-chemical (M-C) process. The long penetration period needed for pulping wood chips under pressure is entirely avoided. Experience has shown that optimum conditions for producing a pulp by this process must be present at the start. If any condition, such as amount of chemical, concentration of chemical, consistency, temperature, available power, or speed of rotation of the pulping mass, is less than optimum, best results will not be obtained.

The M-C process is now being used commercially to pulp straw in mills in Holland, England, and Pakistan, and a new mill to use the process is being constructed in Portugal. In Mexico, a mill is producing market pulp from depithed bagasse by this process. The Mexican mill pulps at a starting consistency of 13 percent while other mills use 10 to 12 percent. In pulping bagasse, all screenings may be repulped. Yields of pulps made commercially will closely approach crude yields shown in the tables. The Mexican company has carried on considerable development work, with the result that pulps with unexpected properties, such as good tearing resistance, suitable for good wrapping papers are being manufactured. Results obtained by the use of this process are illustrated in tables which follow and will be discussed appropriately.

CORRUGATING MEDIUM FROM BAGASSE

Stiffness and crush resistance so necessary for high-grade corrugating medium are attributed to the high-pentosan content of pulps used in its manufacture. Sugarcane bagasse and wheat and rye straw contain higher amounts of pentosans and lesser amounts of lignin than any hardwoods from which standard pulps for corrugating manufacture are presently made. They represent therefore preferred raw materials for making corrugating medium, providing proper pulping methods are used.

Several years ago, at the request of executives of the strawboard industry of the United States, the Northern laboratory undertook a study of pulping methods to bring about improved physical properties in corrugating medium made from wheat straw. This research (12) showed that use of lime as a pulping chemical was responsible for production of a softer medium, but that when caustic soda was substituted as a pulping agent the medium manufactured was stiffer and more crush resistant. When mild pulping conditions used in the M-C process for pulping straw with caustic soda were substituted for the pressure methods conventionally used with this chemical, even higher grade pulps resulted.

Methods for producing high-grade pulps to make corrugating medium from bagasse have been extensively explored by the Peoria group. Typical results obtained are shown in Table 10. It will be noted that pulping the Lockport whole bagasse with a mixture of lime and caustic soda by the M-C process produced a weak pulp as compared with pulp from the same material pulped with caustic soda alone by the conventional pressure method. When 8 percent caustic soda was used by the M-C process, a still better pulp was obtained. When the latter conditions were used to pulp the Lockport separated fiber, an even more acceptable pulp was obtained, as indicated particularly by the higher freeness; e.g., a pulp capable of faster running on the paper machine, and by the improved bursting and tensile strength.

Results obtained on pulping samples of bagasse (variety F. 31-436) from Clewiston, Florida, are very interesting. The samples marked "whole" had been screened before baling to remove about one-third of the pith and dirt. The lower freeness and other physical properties of the pulp made from them, as compared with the pulps from cook Nos. 1255 and 1229, using separated fiber pulped by either the pressure or the M-C process, are striking. Pulp made from whole bagasse by cooking under pressure is freer and stronger than the same material cooked with the same amount of chemical by the M-C process. This is because the pressure cook destroys more of the pith than the M-C method, as is indicated by the higher yield obtained by the latter method. When the pulps produced from separated fiber by the pressure and M-C processes are compared, it will be observed that the pressure method produces a slightly freer pulp, but of lower bursting and tensile strength and in slightly lower yield. When 12 percent lime was substituted for 8 percent caustic in pulping the whole Florida bagasse by the M-C method, a much weaker pulp, of lower crush resistance and freeness was produced. Both pulps from whole bagasse were so slow draining that they would run only slowly on the paper machine. If pulps of this quality only could be made available, a cylinder-forming machine would be preferable to a Fourdrinier machine.

Comparison of results obtained by pulping samples of Hawaiian bagasse (variety 8 560) brings out essentially the same relationships as observed with the Florida bagasse.

It may be concluded from this work that pulps suitable for making low-grade corrugating medium can be made from whole or screened bagasse by cooking with lime, or lime and caustic soda or caustic soda alone, using either pressure or M-C methods. All of these pulps will drain slowly and will require addition of waste papers or considerable washing to be run at paper-machine speeds normal to modern operations. The lime-cooked pulps will be found deficient in strength particularly crush resistance, as compared with caustic-cooked pulps. Using depithed fiber as a raw material, superior pulps are produced by use of caustic soda with any of the pulping methods. The M-C process in general produces pulps as strong or stronger, and in higher yields.

SEMICOMMERCIAL PRODUCTION OF SHIPPING CONTAINERS FROM FLORIDA AND HAWAIIAN BAGASSE

A contract was made by the U.S. Department of Agriculture with the New York State College of Forestry, Syracuse, N.Y., under the Research and Marketing Act, to carry out the manufacture of shipping containers using bagasse as a raw material. Based on data, of which the results shown in Table 11 are representative, it was decided to use the M-C process to produce both corrugating and liner-board pulps. Tonnage lots of both Florida and Hawaiian bagasse were secured. A portion of the Florida whole bagasse was depithed at Syracuse, using the Hydrapulper method developed by the Northern laboratory. The Hawaiian Sugar Planters' Association used the same method in their Hawaiian pilot plant and shipped both whole and depithed bagasse to Syracuse.

The lots of bagasse were pulped at Syracuse in an 8-foot Hydrapulper which was somewhat deficient in rotor speed and in power. Results of the physical tests on some of the representative pulps so produced are given in Table 12. Pulp made from the whole Florida bagasse was so slow draining that it would not run either on the Fourdrinier or the cylinder wet end of the paper machine. The pulp also contained grit. Only by rewashing the pulp, after suitable dilution by passage twice over a decker could the pulp be made free enough to run and produce satisfactory board. Physical properties of this pulp given in Table 12 are representative of the washed pulp and are very similar to the properties obtained by pulping depithed Florida fiber under similar conditions. Thus, the whole bagasse actually was depithed by a combination of chemical and mechanical methods. Corrugating pulps from whole bagasse and from separated fiber were produced by using 12 percent caustic soda on the basis of oven-dry material. The liner-board pulps were made from separated fiber with 16 percent caustic. It will be observed that pulps obtained by cooking with the higher percentage of chemicals are somewhat freer and stronger.

In this connection it is interesting to compare the results obtained commercially in Mexico by pulping with 12 percent caustic in a 10-foot Hydrapulper, using fiber separated from Mexican bagasse.

In making the corrugating medium at Syracuse, 85 percent bagasse pulp and 15 percent waste corrugating were used as the furnish, excepting in one case (HFCX, Table 13) in which 100 percent Hawaiian corrugating pulp was used. Liner boards from both Florida and Hawaiian fiber were made from a mixture of 50 percent bagasse and 50 percent virgin kraft wood pulp, and in two cases with Florida bagasse, 25 percent and 75 percent kraft pulp, respectively. As a control on machine operation, corrugating medium was made from 85 percent commercial semichemical hardwood pulp and 15 percent waste corrugating, and liner board from 100 percent virgin kraft wood pulp. Physical properties of boards made are given in Table 13. Various corrugating media and liner boards were combined into 200-pound-test container board in a commercial box plant. Physical properties of the various combinations are shown in Table 20. The superior strength of combinations using corrugating medium from bagasse, as compared with medium made from semichemical hardwood pulp or commercial corrugating medium, is significant. The combination GL-HFCX, with crush resistance of 88 (Table 20) is remarkable and this board is actually too stiff to be practical for use in ordinary shipping container manufacture.

Three sizes of containers, manufactured commercially from these combinations, were subjected to laboratory tests and to commercial shipping tests. Results were satisfactory in all cases, showing that corrugating medium made from depithed bagasse by the M-C process would meet or surpass the highest present commercial standards. Liner boards made from 50 percent or more bagasse were not the equal in quality to 100 percent kraft liner board, but they would meet most of the less-exacting world industrial requirements. Excepting for tearing resistance, the liner board (FFLY, Table 13), containing 25 percent bagasse and 75 percent virgin kraft, compares favorably with the properties of 100 percent kraft liner.

FINE PULPS FROM BAGASSE FOR UNBLEACHED OR BLEACHED PAPERS

Unbleached or bleached pulps suitable for use in printing and other fine papers can be made from either whole or partly screened bagasse or better, from pith-free fiber. The effects of pith in increasing chemical costs, in producing slow draining, weak pulps, and in causing difficulties in bleaching have already been discussed. As higher grades of pulp are required, these difficulties will, of course, become more acute. For obtaining fine pulps from bagasse, caustic soda, kraft, or neutral sulfite, may be used as chemicals with the conventional pressure processes. Amounts of chemicals required will increase as higher quality pulps are produced. The Celdecor and M-C processes also produce fine pulp, using more chemicals than for preparing pulps for corrugating media or liner boards. Some of the pulps produced by these various methods may be bleached to a brightness of about 70 by a one-stage process. Depending on the amount of pith, dirt, and lignin present, others will not easily produce bright pulps except by use of multistage bleaching processes. To obtain a brightness of 80 to 83, the conventional three-stage bleaching process generally will be found satisfactory with pulps made from depithed fiber. Pulps produced by the three-stage process are stronger and require less chlorine than when bleached to the same brightness by the one-stage process. Pulps containing high amounts of dirt and pith require larger amounts of chlorine for bleaching, which tends to produce weaker pulps in lower yields. In some cases it appears impossible to obtain pulps of high brightness by starting with low-grade, dirty bagasse. Satisfactory pulps for fine papers cannot be made by the use of lime or mixtures of lime with caustic chemicals.

Fine Pulps from Depithed Fiber:

In order to obtain a comparison between pulping depithed fiber under pressure and by the M-C process, tests were made using kraft chemicals and caustic soda.

Data, given in Table 14, show that in general crude yields of pulp obtained by the M-C process are higher than those obtained by the pressure process, as is also often the case with respect to screened yields. It must be noted that results shown in this table may be somewhat misleading, as compared with results obtained in commercial practice, since in commercial practice screenings obtained in one cook would be returned to the succeeding cook for repulping. On the other hand, lignin contents of pressure-cooked pulps are lower in all cases as are also chlorine requirements for bleaching in one stage to 70 brightness. The relation between the other physical characteristics of pulps made by the different methods is somewhat indeterminate, depending on the particular sample of bagasse which was pulped.

This table also contains data on pulping of Hawaiian bagasse under pressure, using kraft chemicals in increasing concentrations. It will be noted that the first two cooks, using 8 and 10 percent kraft chemicals were not satisfactory as indicated by low yields of screened pulps. With 12 and 14 percent kraft chemical, the crude yields decreased and screened yields increased. Lignin content of the pulps and the chlorine requirements for bleaching both decreased. Pulp produced with 14 percent kraft chemicals was best from the standpoint of physical properties. Pulping of Hawaiian bagasse was more difficult than for the other samples studied and pulp produced was not as strong.

Referring to the effect of screenings, Table 15 presents some interesting data. In preparing a rather large lot of M-C pulp for bleaching and manufacturing into paper in a cooperative study at the Forest Products Laboratory Madison, Wis., 14 cooks (1062-1075) were made on Florida bagasse. In making the composite lot, screenings from each cook were returned to the succeeding cook but in the first cook. No. 1062, screenings were not repulped. It will be noted that the composite lot and pulp from the first cook agree in freeness, bursting, and tensile strength, but is superior in tear and in fold resistance. When the latter lot was bleached at the Forest Products Laboratory, the pulp was found to be lower in freeness but superior in other physical properties to the unbleached pulp.

In order to determine directly the effect of repulping screenings, cook 1139 was carried out without repulping the screenings. Screenings were repulped in cooks 1140-1141. Pulp prepared from the screenings had higher freeness, the same Mullen and tensile strength properties, considerably higher tearing resistance and somewhat lower double fold. Screenings come largely from the dense rind fibers of the bagasse which are somewhat difficult to penetrate. It has long been known that rind fibers contain fiber elements of a longer dimension than fibers from fibrovascular bundles, an effect which shows up clearly in the higher tearing resistance of pulp from screenings.

Properties of another composite pulp made from bagasse fiber in the 8-foot Hydrapulper at the New York State College of Forestry, in which screenings were returned to succeeding cooks, are shown in this table. Properties of the bleached pulp produced from it in a three-stage process at one of the plants of the St. Regis Paper Company are also given. It will be noted that the unbleached pulp was similar in properties to the unbleached pulp used at the Forest Products Laboratory. The New York State College of Forestry pulp had higher physical strength properties after bleaching. In this connection, reference is made to the bleached Celdecor commercial Indian bagasse pulp which is softer and has considerably lower strength properties than the bleached M-C pulps.

A study was also made using increasing amounts of chemicals in pulping depithed fiber by the M-C process. Data representative of this study are presented in Table 16, a review of which shows that there is little decrease in yield or increase in physical properties of pulps after the optimum amount of chemical has been used.

When pressure pulping is used, pulp yields are lower and a smaller amount of screenings is obtained, which appear to be due to a better penetration of rind fibers and probably to greater destruction of fibrovascular bundle fibers. By increasing the severity of pressure cooking conditions, the yield of pulp is further decreased. On the other hand, with the mild conditions of the M-C process, it is more difficult to penetrate rind fibers, but less destruction to fibrovascular bundle fibers results. Over-all yields of screened pulps are not only higher in the latter process, but by repulping the screenings a still larger yield of pulp will be obtained as compared with pressure-cooking methods. While pressure cooking reduces the amount of chlorine required for bleaching, it is evident that extremely high-grade unbleached and bleached pulps can be made from depithed bagasse fiber by the M-C process.

Figure 1 illustrates the strength characteristics of unbleached depithed fiber bagasse pulp produced by the M-C process as compared with unbleached commercial softwood sulfite and commercial softwood kraft pulps. The bagasse pulp is superior to the unbleached sulfite pulp in all of its properties excepting tearing resistance but is not as strong as the kraft wood pulp. Pulps made from the better grades of wheat (13) straw by the M-C process compare closely in physical properties with pulps made from depithed bagasse.

FINE PAPERS FROM BAGASSE

Wrapping and Bag Papers:

The composite pulp referred to in Table 15, cooks 1062 to 1075, was blended with commercial kraft wood pulp to produce wrapping and bag papers on the paper machine of the Forest Products Laboratory. The wrapping paper was made from a blend of 50 percent bagasse pulp and 50 percent kraft pulp, both unbleached, and as a control this grade of paper was also made from 100 percent kraft wood pulp. The bag paper was made from a blend of 25 percent bagasse pulp and 75 percent kraft wood pulp and a control run of 100 percent kraft wood pulp was also made. It will be noted from data in Table 17 that, with the exception of tearing resistance, the wrapping and bag papers made with bagasse have somewhat better strength characteristics than those made from 100 percent kraft wood pulp. The table also includes tests made on wrapping and bag papers produced in Peru from mixtures of bagasse pulp, kraft pulp, and waste. The Philippine company producing paper from bagasse reports tests made on handsheets from blends of Celdecor bagasse pulp and American kraft wood pulp. In this case also use of mixtures of bagasse pulp and kraft wood pulp produced wrapping papers superior to papers made from 100 percent wood pulp, excepting in tearing resistance. This same phenomenon has been observed in bags and wrappings made from blends of M-C wheat straw (13) pulp and kraft softwood commercial pulps. Wheat straw pulps produced by the neutral sulfite process in Italy are frequently blended with kraft wood pulps in order to produce better wrapping and bag papers.

The reason for this apparent paradox is that fibers of straw and bagasse pulps greatly improve the formation of papers made from the blends, so that kraft fibers contribute a higher proportion of their inherent strength to the papers so made.

This finding is of great commercial importance because it indicates the possibility of manufacturing very high quality bag and wrapping papers by the use of properly prepared blends of bagasse and wood pulps. This could lower the import requirements of kraft wood pulps in countries where long-fibered pulpwoods are not available. Pulps from such fibers as abaca, sisal, hemp, ramie, and flax can be added to the shorter fibered bagasse pulps to produce papers of extremely high tearing resistance (14).

Newsprint:

Much of the discussion of the use of bagasse for making newsprint has appeared in the lay press and is the cause of a great deal of confusion, which arises largely from the definition of the word newsprint.

It has been demonstrated numerous times that a paper can be made from 100 percent bagasse pulp which will run on fairly high-speed printing presses such as are used by newspaper publishers (15). If sufficient filler and opacifying material are added to bagasse pulp, the show-through and ink penetration of the paper will be satisfactory, but it will not have the same appearance or feel generally associated with newsprint. Newsprint as known in most countries consists of a blend of mechanical pulp, 75 to 85 percent, and chemical pulp, 15 to 25 percent. When Northern spruce or hemlock groundwood is used, the chemical pulp is nearly always spruce or hemlock sulfite. When Southern pine or eucalyptus groundwood is used, the chemical pulp is bleached kraft. Properties of ink absorption, high opacity, and softness of standard newsprint are to be attributed almost entirely to the mechanical pulp. In general, the printing quality of newsprint improves as the amount of chemical pulp is reduced.

From the commercial standpoint, the question of using 100 percent bagasse pulp for the manufacture of newsprint, magazines, or other types of low-quality printing papers will depend on whether publishers in that particular country will accept this type of product in lieu of a product composed largely of mechanical pulp. If mechanical pulp is entirely unavailable, then there should be no question of the publishers' attitude. On the other hand from a long-term view, mechanical pulp can be produced at a lower cost than any chemical pulp. Thus it might be that for a time a country, being deficient in mechanical pulp, would use paper made entirely from bagasse pulp until papers based on a larger percentage of groundwood became available. History shows that newspaper publishers constantly demand lower priced and better newsprint, which will result from, available lower priced mechanical pulps.

There seems to be no doubt that chemical pulps such as unbleached sulfite or bleached kraft, presently used in manufacture of newsprint in various countries, can be replaced by bleached bagasse or bleached straw pulps. Indeed, there is reason to believe, that because of the high tensile strength of bleached pulps made by the M-C process from bagasse and straw, some of the weaker groundwoods such as eucalyptus or Southern pines would be converted to higher grade printing papers than are made at present.

Tests have been run on making newsprint from mixtures of bagasse and mechanical wood pulps on the paper machines both at the Forest Products Laboratory and the New York State College of Forestry. Properties of the bleached bagasse pulps used in making these papers are reported in Table 15. Proportions of bagasse and mechanical pulps used and the characteristics of the papers are given in Table 18. Papers made from these blends meet the printing and physical standards for newsprint in the United States. The formation of the papers made with bagasse pulp is better than that obtained with the all-wood pulp furnish, because of the action of fine bagasse fibers in improving formation. Improvements in formation of newsprint improve printing qualities, particularly of half tones. Tests made in an effort to produce a somewhat stiffer newsprint from Southern pine groundwood show that addition of 15 to 20 percent bleached bagasse pulp to a furnish of 80 percent mechanical pulp and 20 percent bleached kraft pulp produced a sheet comparable to Canadian newsprint.

Physical properties of newsprint made in Peru and India from blends of bagasse and other fibers are also shown in Table 18. In addition, properties of three of the newsprint papers made by the U. S. National Bureau of Standards (16) from 100 percent bagasse are included. Paper No. 1 of the Bureau of Standards' group was judged to be best from the standpoint of printing, softness, and opacity. This paper had a very high ash content, the opacity having been increased by use of titanium dioxide. Analysis of results would indicate that had equal amounts of filler and titanium dioxide been used in making the other two papers, equal opacity and printability would probably have been obtained. Finally, this table also gives properties of commercial newsprint used in the United States.

Writing and Other Fine Papers from Bagasse:

Part of the lot of pulp bleached at the Forest Products Laboratory, cooks 1062-1075, Table 15, was also used for manufacture of bond, magazine-book, and printing papers on the Forest Products Laboratory paper machine. Physical characteristics of these papers are reported in Table 19. Bond and magazine-book papers made with blends of bagasse pulp compared favorably with the same grade of papers made entirely from wood pulps, and showed improvements in formation. The paper, MR-3590, using 100 percent bagasse pulp was lacking in opacity and had a tendency to be somewhat dense with a hard surface, but when 25 percent of clay was added to the pulp, MR-3591, a very good opaque printing paper was obtained. This table also reports tests on a printing paper composed of 100 percent bagasse made in Peru.

Because of information now available on commercial use of bagasse pulps and because of the very great similarity of pulps produced from depithed bagasse and from straw, it is safe to conclude that a very wide field is open for use of unbleached and bleached bagasse pulps, particularly those made from depithed fiber, for the manufacture of fine and specialty papers. Tabb (17) has recently given a very good summary of the properties of straw pulps and how they may be used as blends with other pulps to produce fine and specialty papers.

Because of the character of bagasse fiber, its addition in rather small percentages; e.g., in the neighborhood of 20-30 percent, to almost any pulp with which it may be blended will be found to improve the formation characteristics of papers made from it. Improvement in formation makes better papers for printing and also for waxing. The high-pentosan content of pulps from bagasse makes their beating or refining possible in much less time and at lower cost than possible with wood pulps. Experience shows, however, that it is desirable to beat these pulps. Best results are not obtained by using unbeaten unbleached or bleached bagasse pulps as blends with other pulps. The high-pentosan content of these pulps also is responsible for their tendency to form denser papers which points to their use in bringing about a better handle in many kinds of papers, such as bank, bond, writing of all sorts, and account books. Pulps of this sort are useful in producing a hard surface on tag papers and in closing the surface of papers used for coating or for lithography.

Bagasse pulps, particularly those made by the M-C process, are suited for making glassine. Glassine papers are made from straw pulps of similar characteristics in Italy and Germany.

If it becomes necessary to make papers using bagasse alone, lack of opacity in such papers and their tendency to be dense can be overcome by the addition of well-known mineral fillers. The fine fibers of bagasse pulp result in a higher retention of fillers, and generally the cost of mineral filler is below the cost of bleached pulp. The softness of papers made from 100 percent bagasse pulp can be controlled to a considerable extent also by the addition of fillers.

SUMMARY

From the standpoint of necessity owing to unavailability of wood or other pulps, it is possible to manufacture usable papers or boards from pulps made from whole or screened bagasse but these will be of low quality. Pulps made by cooking with lime will be useful only in making low-quality board or wrappings. Waste papers if available can be used to advantage in the manufacture of such products.

By pulping with the pressure, Celdecor, or M-C processes, using chemicals composed of or containing caustic soda, much higher grade products including bleached pulps can be made from whole or screened bagasse. When bagasse pulps and waste papers alone are available, use of liberal amounts of fillers in making printing and other higher grade papers is advisable. By using such methods, boards as well as printing papers of various quality can be produced which will be acceptable in many markets. Much better results will ensue if mechanical wood pulps or kraft pulps made from tropical or hard woods are available for blending with bagasse pulps. In such cases the best use for bagasse pulps will be as blends with virgin wood pulps and such waste papers and fillers as may be available. Using various such combinations will make possible the manufacture of a much wider range of fairly good to good papers.

Best results can be expected from pulping only depithed bagasse fiber. If commercial uses for separated pith, such as for fuel, feed, or paper filler, can be found, costs of such depithed pulps may be found to be lower than those of pulps made from whole or screened bagasse. Such bagasse pulps can be used solely for manufacture of highest quality corrugating board medium and also for the manufacture of glassine and certain kinds of waxing papers. When these unbleached pulps are blended with kraft or sulfite softwood pulps, superior wrappings, bag, and multiwall bag papers and liner boards can be manufactured. When pulps are bleached and blended with bleached mechanical pulps or bleached chemical wood pulps, a wide variety of very high quality printing and specialty papers becomes available. These bleached bagasse pulps can replace other chemical pulps in blends with mechanical wood pulps to produce newsprint, magazine-book, coated book, and other papers containing large amounts of mechanical pulps. Furthermore, the high tensile strength of these bagasse pulps when produced by the M-C process suggests that weak mechanical pulps might find a much wider use in the manufacture of good papers.

If it should prove expedient to make newsprint from 100 percent bagasse pulp and filler, a collateral market for use of bleached pulp in printing, writing, and other papers should be rapidly developed to provide for the loss of the newsprint market in the event that mechanical pulp or lower cost imported newsprint becomes available.

In selecting pulping methods, consideration should be given not only to the cost elements, such as low initial capital investment, maintenance, and operating costs, but also to simplicity and utility of equipment, flexibility of changing processing conditions to meet changing pulp requirements, and ease of process control. Bagasse is a variable raw material. The paper and board industry in any country is bound to expand with time. Competition in world markets will increase. It is desirable and should be possible to design new mills with great flexibility so as not only to manufacture the best products possible from bagasse and other raw materials available in the local market, but also to provide increasingly better products and products of wider use as the market expands or as other types of pulps and raw materials become available for blending with bagasse pulps.

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Table 1. Physical composition of various varieties of sugarcane. Basis, percentage of dry matter

Constituent	Louisiana Purple	Java				
		Cheribo	No. 36	No. 100	No. 139	No. 247
	%	%	%	%	%	%
Pith	24.6	25.6	20.0	22.8	20.0	20.0
Bundles	18.6	31.5	26.5	25.4	36.0	26.1
Rind	56.7	42.9	53.5	51.8	44.0	53.9

Table 2. Variations in true fiber and pith content of certain varieties of Florida sugarcane. Percentage based on dry bagasse free from dirt and solubles

Cane variety	Fiber	Pith	Ratio: $\frac{\text{Fiber}}{\text{Pith}}$
	%	%	
F. 31-436	69.6	30.4	2.289
P.O.J. 2725	65.4	34.6	1.890
Cl. 38-32	78.1	21.9	3.566

Private communication from Dr. B. A. Bourne, United States Sugar Corporation, Clewiston, Florida, October 1953.

Table 3. Proximate physical analysis of various samples of whole bagasse. Results reported on original bagasse oven-dry basis.

Type of whole bagasse	Florida variety F. 31-962 (1952)	Florida variety Cl. 41-223 (1952)	Louisiana Thibodaux stored (1952)	Hawaiian variety 8560 (1952)	Puerto Rico Aguirre (1951-52)	Philippine Islands Negros (1952)
	%	%	%	%	%	%
Fiber	58.0	60.7	64.4	60.5	60.1	68.6
Pith	22.8	24.3	25.2	32.9	25.5	23.8
Solubles, dirt, and loss	19.2	15.0	10.4	6.6	14.4	7.6

Table 4. Proximate analysis of various types of bagasse (All values except moisture on oven-dry basis)

NRRL No.	Material	Moisture	Ash	Lignin	Pentosans[a]	Extractives in			Cross and Bevan Cellulose				
									C and B cellulose		Alpha as run		Alpha-basis original - ash and pentosan free
						Hot water	Alcohol benzene	1% NaOH	Ash free	Pentosans in	Ash free	Pentosans in	
		%	%	%	%	%	%	%	%	%	%	%	%
1267	Louisiana whole bagasse - stored (Lockport - 1941)	4.1	2.9	21.3	29.4	4.0	1.7	32.9	58.4	29.3	67.2	6.1	36.8
1267	Louisiana bagasse fiber - stored (Lockport - 1941)	6.8	2.0	20.7	30.0	2.4	1.6	28.4	61.4	31.7	70.0	10.0	38.7
1267	Louisiana bagasse pith - stored (Lockport - 1941)	12.2	4.6	21.3	29.9	3.1	1.7	36.1	54.6	30.3	62.8	5.7	32.3
1740	Louisiana whole bagasse - fresh (Houma - 1941)	4.9	2.4	18.9	30.0	8.8	6.0	35.9	53.3	27.9	67.3	7.0	33.4
1740	Louisiana bagasse fiber - fresh (Houma - 1941)	9.7	2.2	19.9	32.5	3.4	2.0	30.5	59.0	29.6	67.7	8.1	36.7
1740	Louisiana bagasse pith - fresh (Houma - 1941)	8.7	6.3	18.0	30.7	3.4	2.9	36.2	52.5	28.7	62.4	6.6	30.6
7892	Florida whole bagasse - fresh dry screened (Clewiston - 1948)	7.3	2.2	18.1	27.9	11.2	10.8	39.9	52.0	26.9	68.0	4.7	33.7
7892	Florida bagasse fiber - fresh (Clewiston - 1948)	7.2	2.0	19.1	30.9	4.5	2.6	31.2	60.4	29.0	67.2	4.5	38.8

-- Continued

Table 4. Proximate analysis of various types of bagasse (All values except moisture on oven-dry basis)

NRRL No.	Material	Moisture	Ash	Lignin	Pentosans^a	Extractives in			Cross and Bevan Cellulose				
									C and B cellulose		Alpha as run		Alpha-basis original - ash and pentosan free
						Hot water	Alcohol benzene	1% NaOH	Ash free	Pentosans in	Ash free	Pentosans in	
		%	%	%	%	%	%	%	%	%	%	%	%
7892	Florida bagasse pith - fresh (Clewiston - 1948)	8.9	3.4	18.2	31.4	4.6	2.5	35.0	53.9	26.2	63.4	4.0	32.8
9940	Florida whole bagasse - variety Cl. 41-223 (Clewiston - 1952)	8.6	1.0	18.2	26.6	15.1	7.0	40.7	48.0	28.1	66.9	4.7	30.6
9941	Florida whole bagasse - variety F. 31-436 (Clewiston - 1952)	10.1	1.6	16.4	27.4	15.5	6.4	43.2	48.8	32.7	66.5	5.3	30.8
9942	Florida whole bagasse - variety F. 31-962 (Clewiston - 1952)	10.5	2.2	18.6	28.7	9.8	8.0	40.0	49.0	26.5	67.7	5.2	31.5
9992	Hawaiian whole bagasse - variety 8560 (1952)	13.2	5.4	21.3	27.7	5.7	3.2	33.9	50.2	27.4	69.6	8.8	31.8
9992	Hawaiian bagasse fiber - variety 8560 (1952)	5.6	2.0	21.1	30.7	2.4	3.6	28.8	56.0	28.8	73.4	10.4	38.3
9992	Hawaiian bagasse pith - variety 8560 (1952)	7.1	3.3	20.0	33.0	1.5	2.1	30.8	53.5	29.7	62.7	6.7	31.5
9333	Hawaiian whole bagasse (Laupahoehoe Sugar Co.)	8.0	1.9	22.5	31.2	3.4	2.1	31.4	55.4	27.7	72.5	8.3	34.3

--Continued

Table 4. Proximate analysis of various types of bagasse (All values except moisture on oven-dry basis)

NRRL No.	Material	Moisture	Ash	Lignin	Pentosans^a	Extractives in			Cross and Bevan Cellulose				
						Hot water	Alcohol benzene	1% NaOH	C and B cellulose		Alpha as run		Alpha-basis original - ash and pentosan free
									Ash free	Pentosans in	Ash free	Pentosans in	
		%	%	%	%	%	%	%	%	%	%	%	%
9573	Hawaiian whole bagasse - variety 1933 (Ewa Plantation)	7.7	2.6	19.3	31.3	4.0	3.6	31.3	55.0	33.4	62.6	8.2	31.6
9851	Hawaiian whole bagasse - variety 1933 (Oahu Sugar Co.)	7.9	3.3	20.1	31.0	2.7	3.4	32.0	52.0	32.4	65.7	7.4	31.7
10081	Puerto Rican whole bagasse (Aguirre 1951, 1952)	7.5	3.9	18.1	29.6	8.0	5.4	27.3	50.9	31.1	63.7	7.0	30.1
10081	Puerto Rican bagasse fiber (Aguirre 1951, 1952)	11.5	1.2	19.8	31.6	1.4	2.7	27.3	59.9	30.4	67.2	5.7	40.2
10081	Puerto Rican bagasse pith (Aguirre 1951, 1952)	4.9	3.2	18.8	31.9	2.8	2.9	30.3	53.9	30.3	60.4	6.4	32.6
10564	Mexican bagasse pith (San Cristobal, 1953)	6.2	4.9	22.4	29.9	7.6	2.3	40.1	46.0	25.5	61.3	5.5	26.6
10566	Philippine whole bagasse (Negros Island, 1952)	10.2	2.3	22.3	31.8	2.8	3.0	31.3	56.8	30.6	70.2	12.5	34.9
10566	Philippine bagasse fiber (Negros Island, 1952)	5.3	1.2	21.8	31.2	1.9	2.1	26.8	62.9	31.9	72.0	9.1	41.2
10566	Philippine bagasse pith (Negros Island, 1952)	3.3	2.6	22.5	33.2	3.6	2.7	36.2	55.4	32.2	66.8	5.7	34.9

[a] Pentosans = furfural x factor 0.8.

Analysis by Northern Utilization Research Branch

Table 5. Proximate analyses of some pulpwoods in percentage of original wood[a]

	Lignin	Pentosans	Extractives				Cross and Bevan cellulose
			Ether	Hot water	Alcohol benzene	1% NaOH	
White spruce	27.8	12.1	1.1	2.1	2.3	11.6	60.6
Jack pine	29.9	14.0	2.4	3.1	4.2	13.9	58.3
Aspen	23.4	22.1	1.1	3.3	1.3	20.4	64.6
Paper birch	26.8	26.5	1.0	2.1	3.2	17.3	60.4
Red gum	21.4	20.7	0.5	2.5	2.0	12.0	60.5

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[a] Pulp and Paper Manufacture, Vol. 1, p. 59, First Ed., McGraw-Hill Book Company, 1950

Table 6. Fiber dimensions of bagasse, straws, and some pulpwoods

	Length in μ			Diameter in μ			Ratio average length to diameter
	Average	Maximum	Minimum	Average	Maximum	Minimum	
Sugarcane[a]							
Fibers	1700	2800	800	20.0	34.1	10.2	85:1
Parenchyma	-	840	-	-	140.0	-	-
Vessel segments	-	1350	-	-	150.0	-	-
Wheat, rye, oat straws[a]							
Fibers	1480	3120	680	13.3	23.8	6.8	111:1
Fibers with thin walls	-	2900	800	-	34.0	-	-
Parenchyma	-	450	-	-	130.0	-	-
Vessel segments	-	1000	-	-	60.0	-	-
Rice straw[a]							
Fibers	1450	3480	650	8.5	13.5	5.1	170:1
Parenchyma	-	350	-	-	82.0	-	-
Vessel segments	-	650	-	-	40.0	-	-
White spruce[b]	-	4200	2300	-	-	-	-
Jack pine[c]	3000	-	-	40.0	-	-	75:1
Aspen[b]	-	1700	800	-	46.0	20.0	37:1
Birch[b]	-	1600	800	-	44.0	20.0	36:1
Red gum[c]	1600	-	-	32.0	-	-	50:1

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[a] F. F. Wangaard, Paper Industry 19, 777-784, 794, October 1937.

[b] E. Hägglund, Holzchemie, p. 20, Zwete Auflage, Leipzig, 1939.

[c] G. Jayme and M. Harders-Steinhäuser, Papier-Fabr. 39 (14), 89-95, April 1941.

Table

Comparative Pulping Characteristics of

Pulping conditions: Chemicals - 8.7% NaOH + 4.3% Na_2S;
Liquids-to-solids ratio 7:1; Time - 1 hr. at 170° C.;

Cook No.	Material Year - Variety	Pulp yields[a] Crude	 Screened .008" cut plate	Chemical analysis[b] Ash	 Lignin	 Pentosans[c]
		%	%	%	%	%
	Louisiana					
1402-3	Lockport, stored 1941 Mixed	63.0	58.9	1.02	2.7	33.5
1421-2	Terrebonne, stored 1948 Mixed	62.8	59.0	1.3	2.9	34.3
1400-1	Houme, fresh 1941 Mixed	63.0	55.2	1.2	2.8	33.4
1406-7	Reserve, fresh 1949 Mixed	63.8	58.8	1.3	3.7	34.2
	Florida					
1404-5	Clewiston, fresh 1948 Probably F.31-436	64.4	58.6	1.6	4.0	33.9
1408-9	Clewiston, fresh 1952 Cl. 41-223	63.9	56.8	1.3	4.4	33.6
1413-14	Clewiston, fresh 1952 F. 31-962	61.6	55.6	1.5	4.1	31.8
1397, 1423	Clewiston, fresh 1953 F. 31-436	61.8	57.8	1.4	3.4	33.6
	Hawaii					
1398-9	Laupahoehoe, fresh 1950 Mixed	62.8	56.0	1.4	3.9	32.8
1411-12	Oahu, fresh 1951 1933	62.4	56.0	2.2	3.2	34.0
	Puerto Rico					
1417-18	Aguirre, fresh 1952 Mixed	58.6	49.2	1.4	4.0	33.3

[a] Basis oven-dry raw material. [b] Basis oven-dry screened pulp.

separated bagasse fibers from various sources

Bleached 70 brightness Hunter. Tests basis weight 47 lb., 25x40-500. TAPPI methods used.

Bleaching			Strength characteristics 500 ml. S.-R.				
Chlorine consumption single[b]	Bleach yield[a]	Initial freeness S.-R.	Bursting strength	Tensile strength	Tearing resistance	Folding endurance	Density
%	%	ml.	pts./ream-lb. x 100	g./ream-lb.	g./ream-lb. x 100	Schopper	g./cc.
5.65	56.2	855	97	176	49	430	0.90
6.8	55.0	860	104	190	55	645	.92
7.0	52.1	845	100	179	54	570	.91
7.6	54.8	865	100	188	57	620	.91
10.2	53.8	815	124	214	48	1000	.96
12.8	57.5	820	118	199	50	800	.94
9.6	52.8	835	98	170	57	640	.88
7.3	52.9	835	126	206	64	880	.89
10.1	53.2	835	90	162	58	405	.86
7.3[d]	51.8	845	97	164	60	580	.86
12.2	45.8	835	102	182	48	615	.89

[c] Pentosans = furfural x factor 0.8. [d] Brightness 65.

Table

Data on pulping bagasse by the soda

Cook No.	Material W = Whole F = Fiber Year - Variety	Cooking conditions			Pulp yields[a]		Chemical analysis[b]		
		Chemical[a]	Time	Temperature	Crude	Screened	Ash	Lignin	Pentosans[c]
		%	hr.	°C.	%	%	%	%	%
1001	Terrebone, La. W Stored 1948 Mixed	12 NaOH	2	170	61	46	4.5	4.2	33
1002	Terrebone, La. F Stored 1948 Mixed	12 NaOH	2	170	62	59	1.3	2.6	32
997	Reserve, La. W (screened) Fresh 1949 Mixed	12 Kraft	2	170	59	50	1.8	5.5	34
998	Reserve, La. F Fresh 1949 Mixed	12 Kraft	2	170	63	57	1.1	4.0	34
1135	Laupahoehoe, Hawaii F Fresh 1950 Mixed	12 NaOH	2	170	62	54	1.1	5.0	31
1149	Laupahoehoe, Hawaii F Fresh 1950 Mixed	12 Kraft	2	170	64	55	1.0	4.4	32
1076	Clewiston, Fla. F Fresh 1951 Mixed	12 NaOH	2	170	69	61	1.5	5.6	34
1078	Clewiston, Fla. F Fresh 1951 Mixed	12 Kraft	2	170	66	61	1.3	4.5	34
908	Clewiston, Fla. W Fresh 1948 Mixed	12 Kraft	2	170	62	52	0.9	4.5	32
909	Clewiston, Fla. F Fresh 1948 Mixed	12 Kraft	2	170	66	61	1.6	3.6	33

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[a] Basis oven-dry raw material. [b] Basis oven-dry screened pulp.

and by the kraft pressure methods

Bleaching			Initial freeness	Strength characteristics 500 ml. S.-R.					
Chlorine consumption single[b]	Brightness Hunter	Bleach yield[a]	S.-R.	Basis weight 25x40-500	Bursting strength	Tensile strength	Tearing resistance	Folding endurance	Density
%	%	%	ml.	lb.	pts./ream-lb. x 100	g./ream-lb.	g./ream-lb.x100	Schopper	g./cc.
13	70	43	830	46	82	162	70	230	0.79
5.4	70	57	840	46	102	184	78	660	.90
15.1	70	46	840	46	85	168	76	420	.80
8.6	70	55	855	46	96	173	83	740	.67
15.1	70	50	860	47	82	162	68	300	.79
13.0	70	-	850	47	84	165	62	350	.81
26	70	50	805	47	110	190	55	980	.84
14.4	70	57	790	46	115	194	60	1120	.90
12	70	49	850	46	69	152	51	160	-
9.0	70	57	790	46	115	196	51	970	-

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[c] Pentosans = furfural x factor 0.8.

Cook Nos. 997 and 908 dry-screened to remove pith.

Table

Data on pulping bagasse by

Cook No.	Material W = Whole F = Fiber Year - Variety	Cooking conditions: Chemical[a]	Cooking conditions: Time	Cooking conditions: Temperature	Pulp yields[a]: Crude	Pulp yields[a]: Screened	Chemical analysis[b]: Ash	Chemical analysis[b]: Lignin	Chemical analysis[b]: Pentosans[c]
		%	hr.	°C.	%	%	%	%	%
923	Lockport, La. F Stored 1941 Mixed	8 Na_2SO_3 3 Na_2CO_3	2	170	68	60	1.2	5.6	30
926	Lockport, La. F Stored 1941 Mixed	10 Na_2SO_3 3 Na_2CO_3	2	170	66	59	1.0	3.4	32
922	Lockport, La. F Stored 1941 Mixed	12 Na_2SO_3 4 Na_2CO_3	2	170	64	61	1.4	2.8	32
925	Clewiston, Fla. F Fresh 1948 Mixed	10 Na_2SO_3 3 Na_2CO_3	2	170	68	57	1.4	3.7	32
1077	Clewiston, Fla. F Fresh 1951 Mixed	10 Na_2SO_3 3 Na_2CO_3	2	170	67	62	0.9	5.3	30
920	Clewiston, Fla. F Fresh 1948 Mixed	15 Na_2SO_3 5 Na_2CO_3	2	170	65	55	-	2.2	33
1258	New Iberia, La. W Fresh 1951 Mixed	13 Na_2SO_3 4 Na_2CO_3	2	170	63	54	2.2	2.4	34
1260	New Iberia, La. F Fresh 1951 Mixed	13 Na_2SO_3 4 Na_2CO_3	2	170	66	58	1.0	2.0	35

[a] Basis oven-dry raw material. [b] Basis oven-dry screened pulp.

9

the neutral sulfite method

Bleaching			Initial	Basis	Strength characteristics 500 ml. S.-R.				
Chlorine consumption single[b]	Brightness Hunter	Bleach yield[a]	freeness S.-R.	weight 25x40-500	Bursting strength	Tensile strength	Tearing resistance	Folding endurance	Density
%	%	%	ml.	lb.	pts./ream-lb. x 100	g./ream-lb.	g./ream-lb.x100	Schopper	g./cc.
12.7	70	56	840	47	90	167	38	220	-
5.9	70	55	840	47	95	180	66	390	-
3.4	70	60	840	47	90	178	44	590	-
9.0	70	49	800	46	121	204	64	1150	-
16.0	70	56	780	47	113	188	63	920	0.87
3.2	70	53	810	46	122	198	53	980	-
6.3	70	52	820	47	83	157	50	160	0.84
5.3	70	56	850	46	101	171	58	410	0.88

[c] Pentosans = furfural x factor 0.8. Cook Nos. 925, 1077, 920, 1258, and 1260 dry-screened to remove pith.

Table

Data on the pulping of bagasse

Cook No.	Material W = Whole F = Fiber Year - Variety	Cooking conditions			Pulp yields[a]		Initial Freeness
		Chemical[a]	Time	Temperature	Crude	Washed	S.-R.
		%	hr.	°C.	%	%	ml.
911	Lockport, La. W Stored 1941 Mixed	5 NaOH 3 CaO	1	98	-	-	510
902	"	6 NaOH	5	140	73	71	690
980	"	8 NaOH	1	98	78	73	660
978	"	8 NaOH	1	98	80	78	750
1187	Clewiston, Fla. W Fresh 1953 F. 31-436	8 NaOH	5	140	61	59	685
1228	Clewiston, Fla. W Fresh 1953 F.31-436	8 NaOH	1	98	70	68	480
1255	"	8 NaOH	5	140	71	69	770
1229	"	8 NaOH	1	98	73	71	680
1410	"	12 CaO	1-3/4	99	-	-	560
1245	Oahu, Hawaii W Fresh 1951 8560	10 NaOH	1	99	68	66	510
1239	Oahu, Hawaii F Fresh 1951 8560	10 NaOH	1	99	75	72	730
1256	"	10 NaOH	5	140	68	67	855

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[a] Basis oven-dry raw material.

to produce corrugating medium

	Strength characteristics 500 ml. S.-R.					
Basis weight 25x40-500 lb.	Bursting strength pts./ream-lb. x 100	Tensile strength g./ream-lb.	Tearing resistance g./ream-lb.x 100	Riehle ring crush lb.	Flat crush lb./sq. in.	Density g./cc.
120	20	45	-	20	-	-
116	50	114	63	34	-	0.68
118	72	139	66	38	-	.73
114	79	152	64	39	-	.82
118	83	166	62	42	-	.78
116	58 (400 ml.)	112 (400 ml.)	110 (400 ml.)	34 (400 ml.)	58 (400 ml.)	.60
120	89	144	66	45	-	.80
118	96	173	66	45	76	.82
117	72	130	70	28	-	.76
121	76 (400 ml.)	131 (400 ml.)	76 (400 ml.)	36 (400 ml.)	64 (400 ml.)	.69
117	83	146	86	37	66	.74
117	90	142	112	40	-	.80

Table

Data on the pulping of Florida
by pressure and mechano-chemical

Cook no.	Material	Cooking conditions				Pulp yields a/		
		Chemical a/	Time	Temperature	pH final liquor	Crude	Screen-washed	Fines
		% NaOH	hrs.	°C.		%	%	%
							Florida Bagasse,	
1187	Whole	8.0	5	140	-	60.7	58.9	1.8
1228	"	8.0	1	98-99	-	70.4	67.7	2.5
1255	Separated fiber	8.0	5	140	-	71.3	69.4	1.9
1229	" "	8.0	1	98-99	10.7	73.2	70.7	2.5
1230	" "	10.0	1	98-99	11.5	72.0	71.0	1.0
1231	" "	12.0	1	98-99	11.9	68.9	63.8	1.3
1244	" "	13.0	1	98-99	11.9	70.2	65.2	3.5
1232	" "	14.0	1	98-99	11.8	69.6	66.0	2.6
							Hawaiian Bagasse,	
1243	Whole	8.0	1	98-99	11.1	72.1	68.4	3.7
1236	Separated fiber	8.0	1	98-99	11.0	76.1	74.2	1.9
1245	Whole	10.0	1	98-99	-	68.5	65.5	2.9
1239	Separated fiber	10.0	1	98-99	11.5	74.8	71.9	2.9
1256	" "	10.0	5	140	-	68.5	67.3	1.2
1240	" "	12.0	1	98-99	11.8	73.0	69.9	3.1
1241	" "	14.0	1	98-99	12.2	72.1	58.3	7.4
1242	" "	16.0	1	98-99	12.2	71.1	62.4	4.8
1251	" "	18.0	1	98-99	12.3	69.4	65.4	4.9

a/ Basis oven-dry raw material.

and Hawaiian samples of bagasse
cooking methods

Chemical analysis b/			Initial freeness S.-R.	Strength characteristics 500 ml. S.-R.				
Ash	Lignin	Pentosans		Bursting strength	Tensile strength	Tearing resistance	Riehle ring crush	Flat crush
%	%	%	ml.	pts./ream lb. x 100	g./ream-lb.	g./ream-lb. x 100	lb.	lb./sq. in.
Variety No. F.31-436, Year 1952								
-	-	-	685	83	166	62	42	-
-	-	-	480	58 (400 ml.)	112 (400 ml.)	110 (400 ml.)	34 (400 ml.)	58 (400 ml.)
-	-	-	770	89	114	66	45	-
1.0	10.3	35	680	96	173	66	45	76
1.7	8.2	33	650	95	182	75	45	75
								Folding
1.0	6.6	36	720	113	190	58	-	540
1.3	5.4	33	720	111	187	56	-	900
1.2	5.9	34	680	117	198	56	-	700
Variety No. 8560, Year 1952								Flat Crush
-	-	-	510	67 (400 ml.)	129 (400 ml.)	72 (400 ml.)	35 (400 ml.)	63 (400 ml.)
-	-	-	700	79	130	92	35	72
-	-	-	510	76 (400 ml.)	131 (400 ml.)	76 (400 ml.)	36 (400 ml.)	64 (400 ml.)
1.8	10.0	33	730	83	146	86	37	66
1.3	8.2	32	855	90	142	112	40	-
1.4	9.4	34	740	89	151	88	40	70
								Folding
1.6	9.1	32	820	81	150	70	-	250
1.6	8.8	31	800	82	155	72	-	280
1.6	9.2	32	795	81	158	72	-	320

b/ Basis oven-dry screened pulp.

Table

Data on large-scale pulping of bagasse by the

Cook no.	Material W = Whole F = Fiber Year - Variety	Cooking conditions: Chemical a/	Cooking conditions: Time	Cooking conditions: Temperature	Pulp yields a/: Crude	Pulp yields a/: Screened
		%	hr.	°C.	%	%
N.Y. College of Forestry	Clewiston, Fla. W Fresh 1952 F. 31-436	12 NaOH 8-ft. Hydrapulper	1.5	99	Pulp passed over decker to remove pith and dirt	
"	Clewiston, Fla. F Fresh 1952 F. 31-436	16 NaOH 8-ft. Hydrapulper	1.2	99	-	-
"	Oahu, Hawaii F Fresh 1952 8560	12 NaOH 8-ft. Hydrapulper	2.0	99	-	-
"	Oahu, Hawaii F Fresh 1952 8560	16 NaOH 8-ft. Hydrapulper	1.5	99	-	-
	Mexican F Stored 1952 Mixed	12 NaOh 10-ft. Hydrapulper	1.0	94	-	-
	Commercial semichemical corrugating pulp	-	-	-	-	-
	Commercial southern kraft liner pulp	-	-	-	-	-

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a/ Basis oven-dry raw material.

mechano-chemical process to make corrugating medium pulps

Chemical analysis b/			Initial freeness S.-R.	Strength characteristics 500 ml. S.-R.				
Ash	Lignin	Pentosans c/		Basis weight 25x40-500	Bursting strength	Tensile strength	Tearing resistance	Riehle ring crush
%	%	%	ml.	lb.	pts./ream lb. x 100	g./ream-lb.	g./ream-lb.x 100	lb.
0.66	7.4	34	710	119	96	163	78	36
.60	7.8	34	820	118	111	182	80	35
1.03	11.7	33	845	119	90	161	86	34
-	-	-	865	120	94	164	94	36
1.1	8.4	38	700	118	88	162	62	39
1.5	14.9	22	605	118	83	148	79	31
1.0	7.1	13	890	116	133	192	197	31

b/ Basis oven-dry screened pulp.   c/ Pentosans = furfural x factor 0.8.

Table

Physical properties of corrugating medium and liner boards with New York State

Designation	Kind of board	Components in %		Basis weight	
		Bagasse	Other	1,000 sq. ft.	25 x 40-500
				lb.	lb.
FFC	Corrugating	85 Florida fiber 1952 F. 31-436	15 waste corrugating	29.7	118
HFC	Corrugating	85 Hawaiian fiber 1952 8560	15 waste corrugating	33.1	106
HFCX	Corrugating	100 Hawaiian fiber 1952 8560	None	33.1	115
CC	Corrugating	85 commercial semichemical pulp	15 waste corrugating	30.3	105
GC	Commercial corrugating	-	-	41.3	143
FFL	Liner	50 Florida fiber 1952 F. 31-436	50 virgin southern kraft	42.7	148
FFLX	Liner	100 Florida fiber 1952 F. 31-436	None	41.3	143
FFLY	Liner	25 Florida fiber 1952 F. 31-436	75 virgin southern kraft	37.0	129
HFL	Liner	50 Hawaiian fiber 1952 8560	50 virgin southern kraft	44.7	155
CL	Liner	-	100 virgin southern kraft	39.7	138
GL	Commercial kraft liner	-	-	43.0	149

made under U. S. Department of Agriculture RMA contract
College of Forestry, 1952

Strength characteristics 500 ml. S.-R.							
Bursting strength	Tensile strength		Tearing resistance		Riehle ring crush		Caliper
	With	Across	With	Across	With	Across	
pts./ream-lb. x 100	g./ream-lb.		g./ream-lb. x 100		lb.		.001 in.
71	143	102	98	105	31	22	8.3
74	104	115	165	95	32	24	8.8
68	170	104	91	96	39	31	9.8
70	168	99	92	111	35	24	9.2
53	143	33	127	199	32	18	11.0
88	188	91	166	218	40	29	11.0
85	167	110	90	94	40	36	9.8
97	189	92	195	191	37	27	9.6
81	164	94	170	221	54	40	12.7
100	191	80	212	272	39	26	10.6
88	158	86	262	313	32	26	13.2

Table

Comparison of results of pulping bagasse
the mechanc-chemical (M-C) process

Cook no.	Material		Cooking conditions			Pulp yields a/		Chemical analysis b/		
	Variety	Method	Chemical a/	Time	Temperature	Crude	Screened	Ash	Lignin	Pentosans c/
			%	hr.	°C.	%	%	%	%	%
1249	Florida, variety F. 31-436, CD. 9941	P	13 kraft	1	170	61.9	55.8	1.3	3.2	32.0
1232		M-C	14 NaOH	1	99	69.6	65.0	1.2	5.9	34.0
998	Louisiana, Cd. 8953	P	12 kraft	2	170	63.3	56.6	1.1	4.0	34.5
985		M-C	15 NaOH	3/4	98	72.1	55.4	1.4	6.1	31.7
1417-1418	Puerto Rican CD. 10081	P	13 kraft	1	170	58.6	49.2	1.4	4.0	33.3
1363		M-C	16 kraft	3/4	99	69.2	58.1	1.3	6.5	33.6
1397-1423	Florida, variety F.31-436, CD. 10366	P	13 kraft	1	170	62.0	57.8	1.4	3.4	33.6
1394		M-C	14 NaOH	3/4	99	69.3	61.1	1.0	6.0	32.9
909	Florida, CD. 7892	P	12 kraft	2	170	66.0	60.6	1.6	3.6	33
921		M-C	15 kraft	3/4	99	71.4	58.0	-	5.1	36
1147	Hawaiian, CD. 9333	P	8 kraft	2	170	70.1	36.5	1.6	9.3	31.3
1148			10 kraft	2	170	66.9	44.3	1.2	6.9	31.5
1149			12 kraft	2	170	64.0	55.2	1.0	4.4	31.8
1150			14 kraft	2	170	61.4	56.4	1.0	2.6	32.9

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a/ Basis oven-dry raw material. b/ Basis oven-dry screened pulp.

fiber by conventional pressure (P) methods and to produce fine paper pulps

Bleaching		Initial freeness	Strength characteristics 500 ml. S.-R.					
Chlorine consumption single b/	Brightness Hunter	Initial freeness S.-R.	Basis weight 25x40-500	Bursting strength	Tensile strength	Tearing resistance	Folding endurance	Density
%	%	ml.	lb.	pts./ream-lb. x 100	g./ream-lb.	g./ream-lb.x 100	Schopper	g./cc.
8.7	70	810	47	115	186	60	680	0.89
12.0[d]	70	850	47	121	193	59	910	.89
8.6	70	855	47	96	173	83	740	.87
-	-	810	46	90	166	82	380	.83
12.2	70	835	47	102	182	48	615	.89
14.3	70	790	46	93	173	64	480	.83
7.3	70	835	47	126	206	64	880	.90
12.6	70	780	46	105	174	63	660	.87
9.0	70	790	46	115	196	51	970	.96
12.5	70	780	46	106	188	44	980	.66
25.4[d]	70	830	47	70.5	151	52	150	.80
13.0[d]	70	840	47	79.5	162	59	270	.80
6.4[d]	70	850	47	84.5	165	62	350	.81
3.4[d]	70	850	47	88.5	154	62	480	.84

c/ Pentosans = furfural x factor 0.8. d/ Three-stage bleach.

Table

Data on large-scale production of fine fiber by the mechano-chemical

Cook no.	Material Year - Variety	Cooking conditions Chemical a/	 Time	Chemical analysis b/ Ash	 Lignin	 Pentosans c/
		%	min.	%	%	°C.
1062	Clewiston, Florida Separated fiber 1950-51 Mixed	15 NaOH	60	-	-	-
1062-1075	Composite bleached at Forest Products Laboratory	15 NaOH	60	1.3	5.7	33
1062-1075	After bleaching 3 stage at FPL	11 chlorine	-	0.6	0.3	34
1139	Clewiston, Florida Separated fiber 1950-51 Mixed	15 NaOH	50	-	-	-
1140-1141	Screenings from Cook No. 1139 Cooked separately	10 NaOH	45	-	-	-
New York College of Forestry	Clewiston, Florida Separated fiber 1952 - F. 31-436	16 NaOH 8-ft Hydrapulper	60	1.4	6.1	32
New York College of Forestry	After bleaching 3 stage at St. Regis Paper Co.	13 chlorine	-	0.2	1.4	33
	From Pakistan, dry-screened bagasse, Celdecor process	-	-	1.2	0.3	34

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a/ Basis oven-dry raw material. b/ Basis oven-dry screened pulp

c/ Pentosans = furfural x factor 0.8.

bleached and unbleached pulps from bagasse process and the Celdecor process

Brightness Hunter	Initial freeness S.-R.	Strength characteristic 500 ml. S.-R.				
		Bursting strength	Tensile strength	Tearing resistance	Folding endurance	Density
%	ml.	pts./ream lb. x 100	g./ ream-lb.	g./ream-lb. x 100	Schopper	g./cc.
-	750	116	192	48	980	-
-	730	115	186	56	1060	0.89
81	700	121	190	58	1120	.97
-	800	116	192	56	930	-
-	890	116	192	66	700	-
-	840	115	184	56	805	.89
80	770	126	207	59	1480	.92
78	810	61	130	56	80	.82

Table

Data on the pulping of depithed

Cook no.	Material Variety	Cooking conditions			Pulp yields[a]		Chemical analysis[b]		
		Chemical[a]	Time	Temperature	Crude	Screened	Ash	Lignin	Pentosans[c]
		%	hr.	°C.	%	%	%	%	%
1231	Florida, Variety F. 31-436, CD. 9941	12 NaOH	1	99	68.9	63.8	1.0	6.6	36.0
1244		13 NaOH	1	99	70.2	65.2	1.3	5.9	33.0
1232		14 NaOH	1	99	69.6	65.0	1.2	5.9	34.0
1394	Florida, Variety F. 31-436, CD. 10366	14 NaOH	3/4	99	69.3	61.1	1.0	6.0	32.9
1395		15 NaOH	3/4	99	70.5	63.6	0.8	5.6	32.6
1396		16 NaOH	3/4	99	68.6	62.3	0.9	6.1	31.9
1241	Hawaii, Variety 8560, CD. 9992	14 NaOH	1	99	72.1	58.3	1.6	9.1	32.0
1242		16 NaOH	1	99	71.1	62.4	1.6	8.8	31.0
1251		18 NaOH	1	99	69.4	65.4	1.6	9.2	32.0

[a] Basis oven-dry raw material.

[b] Basis oven-dry screened pulp.

[c] Pentosans = furfural x factor 0.8

[d] Three-stage bleach

bagasse fiber by mechano-chemical process

Bleaching				Strength characteristics 500 ml. S.-R.					
Chlorine consumption single [b]	Brightness Hunter	Bleach yield [a]	Initial freeness S.-R.	Basis weight 25x40-500	Bursting strength	Tensile strength	Tearing resistance	Folding endurance	Density
%	%	%	ml.	lb.	pts./ream-lb. x 100	g./ream-lb.	g./ream-lb.x 100	Schopper	g./cc.
20.8	70	54.0	720	47	113	190	58	540	0.87
20.1	70	57.0	720	47	111	187	56	900	.86
12.0[d]	70	56.0	850	47	121	193	59	910	.89
17.5	70	55.9	780	46	105	174	63	660	.87
18.0	70	57.0	790	47	107	176	65	680	.87
18.3	70	57.0	770	46	105	172	56	660	.85
18.1[d]	70	49.7	830	46	81	150	70	250	.72
17.4[d]	70	55.4	800	47	82	155	72	280	.71
11.9[d]	70	55.8	790	46	81	158	72	320	.72

Table

Kraft bag and wrapping papers made

Place made	Kind of paper	Run no.	Furnish		
			Bagasse	Wood sulfite	Freeness Canadian
			%	%	ml.
USDA - FPL Madison, Wisconsin	Bag	MR-3643	25	75	
		MR-3645	-	100	
	Wrapping	MR-3644	50	50	
		MR-3646	-	100	
Peru	Bag	8P	67	28	
	Wrapping	3C	55	15	
			Handsheets prepared from blends of		
Philippine[a]			-	100	630
			100	-	510
			50	50	520
			75	25	460

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[a] "Paper from bagasse,"World's Paper Trade Review 134 (13), 860, Oct. 5, 1950.

in part from unbleached bagasse pulp

Physical characteristics									
Basis weight: 25x40-500	Bursting strength	Tensile strength kg.-15 mm. width		Tearing resistance		Folding endurance		Density	Caliper
		MD	CD	MD	CD	MD	CD		
lb.	pts./ream-lb. x 100			g.	g.	Schopper		g./cc.	.001 in.
54.0	96.7	11.9	4.5	58.9	78.1	960	400	0.75	4.0
51.8	75.9	11.3	3.5	74.2	106.0	1100	140	.70	4.1
98.7	101.0	21.1	8.7	122.0	137.0	1200	800	.79	6.9
104.0	78.4	18.5	7.1	227.0	273.0	-	-	.71	8.1
48.0	49.0	6.2	2.9	41.4	54.0	150	27	.62	4.3
107.0	42.0	10.8	6.5	111.0	140.0	-	-	.64	9.5
American wood kraft and Celdecor bagasse pulps									
39.2	89.0	5.6	-	107.0	-	2970	-	.55	3.9
36.9	87.0	5.1	-	51.0	-	450	-	.46	4.5
39.2	101.0	7.1	-	53.0	-	1610	-	.45	4.8
39.8	89.0	6.3	-	47.0	-	2170	-	.52	4.2

Table

Newsprint papers made from

Place made	Run no.	Furnish				Basis weight	
		Bagasse	Wood sulfite	Groundwood	Other	25x40-500	24x36-500
		%	%	%	%	lb.	lb.
USDA -FPL Madison, Wisconsin	MR-3652	30	-	70 spruce-aspen	-	39.5	34.1
	MR-3654	30	-	70 spruce-tupelo	-	30.0	25.9
	MR-3653	-	20	80	-	39.9	34.5
New York State College of Forestry, Syracuse, N.Y.	MR-9	30	-	70	-	39.6	34.2
	MR-8	-	20	80	-	39.0	33.7
Peru		80	10	-	10 waste	42.0	36.3
India		70	-	-	30 bamboo	45.0	38.9
U.S. Dept. Commerce National Bur. of Standards Washington, D.C.	1	100	-	-	-	41.4	35.8
	2	100	-	-	-	38.4	33.4
	3	100	-	-	-	49.5	42.8
Commercial news		-	30	70	-	37.6	32.5

bleached bagasse in whole or part

Physical characteristics										
Bursting strength	Tensile strength kg.-15 mm. width		Tearing resistance Elmendorf		Folding endurance		Density	Caliper	Opacity contrast ratio	Ash
	MD	CD	MD	CD	MD	CD				
lb./ sq. in.							g./cc.	.001 in.	%	%
12.7	3.9	2.2	25.6	28.8	8	3	0.53	4.1	-	-
9.1	3.2	1.7	22.4	25.6	3	1	.40	4.1	-	-
11.2	3.9	2.0	28.8	33.3	6	3	.49	4.5	-	-
9.5	3.1	2.1	16.0	17.3	3	2	.58	3.8	(85 Brt.) 97	8.0
8.0	2.5	1.8	19.8	20.5	2	3	.55	3.9	97	5.4
15.4	4.1	2.3	22.7	25.6	19	8	.72	3.2	-	-
12.6	3.8	2.9	32.0	37.0	10	8	.77	3.2	-	1.2
11.0	3.9	2.1	29.0	43.0	13	7	-	3.2	(MgO) 92	13.2
8.0	3.0	1.8	19.0	18.0	7	5	-	2.9	78	5.4
13.5	4.1	3.0	25.0	24.0	12	11	-	4.1	82	14.9
7.0	2.4	1.2	19.0	23.0	5	1	-	3.5	90	0.24

Table

Bond and other printing papers

Place made	Kind of paper	Run no.	Furnish		
			Bagasse	Wood sulfite	Groundwood
			%	%	%
USDA - FPL Madison, Wisconsin	Bond	MR-3648	50	50	-
	Magazine-Book	MR-3649	25	15	60
	Printing	MR-3590	100	-	-
	Printing	MR-3591	100	-	25% clay
Peru	Printing	-	100	-	-

from bagasse in whole or part

Physical characteristics									
Basis weight: 25-40 500	Bursting strength	Tensile strength kg.-15 mm. width		Tearing resistance		Folding endurance		Density	Caliper
		MD	CD	MD	CD	MD	CD		
lb.	pts./ream-lb. x 100			g.	g.	Schopper		g./cc.	.001 in.
56.9	56.1	9.7	3.4	53.1	64.0	440	45	0.81	3.9
39.2	33.9	4.6	2.2	25.6	30.1	16	4	.54	4.0
41.7	75.8	7.6	4.2	22.4	22.4	330	150	.85	2.7
43.7	38.4	4.9	2.3	24.3	28.8	36	9	.81	3.0
40.0	32.0	3.3	2.3	21.2	25.6	9	6	.67	3.3

Table 20

Physical properties of 200-pound test liner boards made under U. S. Department of Agriculture RMA Contract with New York State College of Forestry, 1952

Combination	Bursting strength	GE puncture (Beach)	Flat Crush
	lb./sq. in		lb./sq. in.
FFL-FFC	257	204	71
CL-FFC	265	219	77
GL-FFC	243	235	76
HFL-HFC	216	212	65
CL-HFC	253	233	68
GL-HFC	265	232	65
GL-HFCX	229	271	88
FFL-CC	269	201	56
HFL-CC	226	185	52
CL-CC	262	224	63
GL-CC	241	228	64
FFL-GC	253	176	27
HFL-GC	225	203	33
FFLX-GC	197	151	25
FFLY-GC	241	185	25
CL-GC	233	203	27
GL-GC	240	203	28

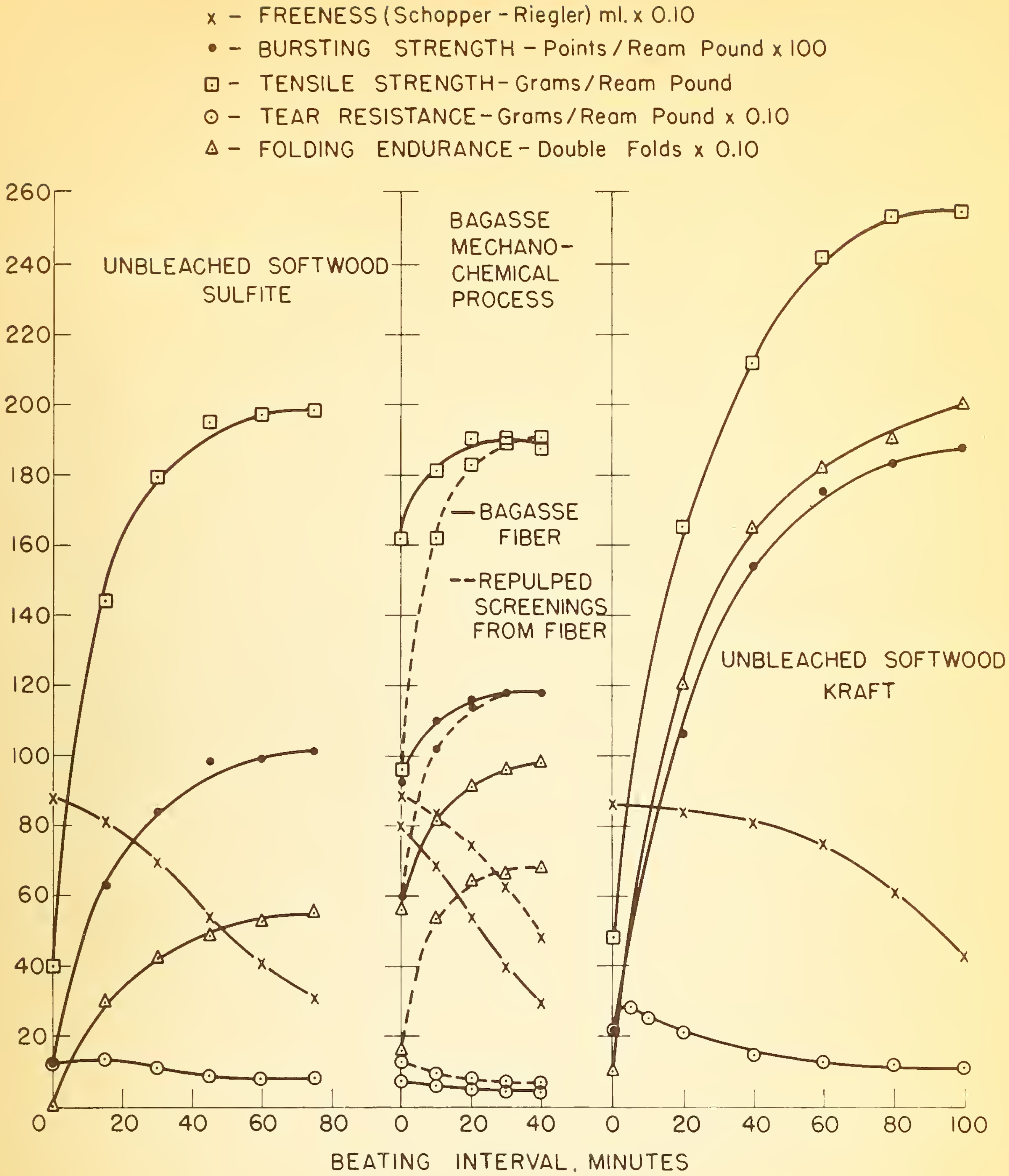

FIGURE 1

Comparison of Strength Data on Mechano-Chemical Unbleached Pulps from Depithed Bagasse Fiber and Repulped Screenings with Commercial Unbleached Softwood Pulps